PHOTOVOLTAIC CHARGE CONTROLLER

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"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Electronics)"

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Signature : ______________________________

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Date : 4 MAY 2009

Specially dedicated to my beloved family

To My Beloved Mother and Dad, My Lovely Sisters & My Sweet Brothers

Mohd Bin Tahar
Wan Kembang Binti Wan Ngah

Dzul Fadli Bin Mohd
Dzul Awatif Bin Mohd
Noor Syafiqa Amira Bt. Mohd
Dzul Haziq Bin Mohd
Noor Huwaida Adeeba Bt. Mohd
Muhammad Aqif Ikhwan Bin Mohd

And those people who have guided and inspired me throughout my journey of education

Thanks for everything…

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ABSTRACT

Photovoltaic or in short term PV is one of the renewable energy resources that recently has become broader in nowadays technology. The demand or future work is looking for high efficiency, more reliable and economical price PV charge controller which is come in portable size has become very popular in PV system. In general, PV system consists of a PV array, charge controller, rechargeable battery and dc load. PV charge controller is very important in PV system. In this project, a PV Charge Controller is designed based on microcontroller (PIC 16F877A) which reduced complexity in the number of electronic components and increased monitoring and regulative functions. This project used dc-dc buck converter circuit which has been simulated using software of OrCAD PSPICE. Pulse width modulation (PWM) will be implemented on a PIC 16F877A to control duty cycle, voltage and current in the PV system and is programmed using software of Microcode Studio. Liquid Crystal Display (LCD) is used to display the voltage and current from rechargeable battery. The benefit of this project is an improvement of efficiency depend on duty cycle and voltage change.

ABSTRAK

Voltan cahaya atau singkatannya PV adalah salah satu daripada sumber tenaga yang dapat diperbaharui yang baru-baru ini menjadi semakin meluas dalam teknologi pada masa kini. Permintaan atau projek di masa hadapan bagi pengawal cas elektrik PV adalah dalam keluaran yang lebih efisien, boleh dipercayai kegunaannya dan harga yang berpatutan dalam bentuk yang mudah dibawa semakin popular dalam sistem PV. Secara umumnya, sistem PV mengandungi susunan PV, pengawal cas elektrik, bateri cas semula dan beban arus elektrik terus. Pengawal tenaga elektrik sangat berguna dalam system PV. Di dalam projek ini, pengawal cas elektrik photovoltaic direka berdasarkan pengawal terbenam (PIC 16F877A) di mana ia mengurangkan kekompleksan dalam penggunaan jumlah komponen elektronik dan meningkatkan pengawasan dan fungsi pengaturan. Projek ini menggunakan litar *"dc-dc buck converter"* yang telah dihasilkan menggunakan perisian *"OrCAD PSPICE"*. Nadi keluasan modulasi (PWM) akan dilaksanakan menggunakan PIC 16F877A untuk mengawasi kitaran duti, voltan dan arus aliran elekrik dalam system photovoltaic dan seterusnya diprogramkan menggunakan perisian *"MicroCode Studio"*. Paparan cecair Kristal (LCD) pula digunakan untuk mempamerkan bacaan voltan dan arus aliran elektrik daripada bateri caj semula. Kelebihan projek ini adalah peningkatan kecekapan yang bergantung kepada kitaran duti dan perubahan voltan.

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LIST OF SYMBOLS

D	Duty Cycle
f	Frequency
V	Voltage/Potential difference
L	Inductance
R	Resistance
C	Capacitance
I	Current
T	Time

LIST OF ABBREVIATIONS

D.C.	Direct Current
ADC	Analog to Digital converter
PWM	Pulse Width Modulation
PV	Photovoltaic
IC	Integrated Circuit
ICD	Circuit Debugging
IDE	Integrated Development Environmental
LCD	Liquid Crystal Display
DIP	Dual Inline Package
L.E.D	Light Emitting Diode
PIC	Programmable Interface Controller
RISC	Reduced Instruction Set Computing
OSC	Oscillation
ESR	Equivalent Series Resistance
CCM	Continues Current Mode

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Photovoltaic or in short term PV is one of the renewable energy resources that recently has become broader in nowadays technology. PV has many benefits especially in environmental, economic and social. In general, a PV system consists of a PV array which converts sunlight to direct-current electricity, a control system which regulates battery charging and operation of the load, energy storage in the form of secondary batteries and loads or appliances. A charge controller is one of functional and reliable major components in PV systems. A good, solid and reliable PV charge controller is a key component of any PV battery charging system to achieve low cost and the benefit that user can get from it. The main function of a charge controller in a PV system is to regulate the voltage and current from PV solar panels into a rechargeable battery. The minimum function of a PV charge controller is to disconnect the array when the battery is fully charged and keep the battery fully charged without damage. A charge controller is important to prevent battery overcharging, excessive discharging, reverse current flow at night and to protect the life of the batteries in a PV system. A power electronics circuit is used in a PV charge controller to get highest efficiency, availability and reliability. The use of power electronics circuits such as various dc to dc converters topologies like buck converter, boost converter, buck-boost converter and others converter topology as power conditioning circuitry to provide a desired current to charge battery effectively.

1.2 OBJECTIVES

(i) To design Photovoltaic (PV) Charge Controller by using PIC microcontroller type.

(ii) To monitor voltage and current as the input of the rechargeable battery and display on the Liquid Crystal Display (LCD).

1.3 SCOPE OF PROJECT

(i) The PV charge controller that designed in this project will be implement PIC microcontroller in it.

(ii) This project concentrates on DC-DC Converter.

(iii) This project will use PIC microcontroller to control the voltage and current at certain values that have been set which are act as input of the rechargeable battery and displays all the results of voltage, current, power and percentage remaining rechargeable battery on the LCD.

1.4 PROBLEM STATEMENT

Most of the PV charge controller nowadays just uses LED to indicate the operating status of the rechargeable battery. It is hard to know the values of the rechargeable battery that have been used such as voltage, current and others. Besides most of PV charge controller is expensive depends on the total cost of PV system that has been used.

1.5 THESIS OVERVIEW

This Photovoltaic Charge Controller final thesis is arranged into following chapter:

Chapter 1: Basically is an introduction of the project. In this chapter, provides the background of the project, objectives, scope of the project, problem statement, and also the thesis outline.

Chapter 2: Focuses on literature reviews of this project based on journals and other references.

Chapter 3: Mainly focused on methodologies for the development of Photovoltaic Charge Controller. Details on the progress of the project are explained in this chapter.

Chapter 4: Presents the results obtained and the limitation of the project. All discussions are concentrating on the result and performance of Photovoltaic Charge Controller.

Chapter 5: Concludes overall about the project. Obstacle faces and future recommendation are also discussed in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Photovoltaic Charge Controller

A charge controller is needed in photovoltaic system to safely charge sealed lead acid battery. The most basic function of a charge controller is to prevent battery overcharging. If battery is allowed to routinely overcharge, their life expectancy will be dramatically reduced. A charge controller will sense the battery voltage, and reduce or stop the charging current when the voltage gets high enough. This is especially important with sealed lead acid battery where we cannot replace the water that is lost during overcharging. Unlike Wind or Hydro System charge controller, PV charge controller can open the circuit when the battery is full without any harm to the modules. Most PV charge controller simply opens or restricts the circuit between the battery and PV array when the voltage rises to a set point. Then, as the battery absorbs the excess electrons and voltage begins dropping, the controller will turn back on. Some charge controllers have these voltage points factory-preset and non adjustable, other controllers can be adjustable. [1]

2.2 Photovoltaic

Photovoltaic (PV) is the field of technology and research related to the application of solar cells for energy by converting sun energy (sunlight or sun ultra violet radiation) directly into electricity. Due to the growing demand for clean sources of energy, the manufacture of solar cells and PV arrays has expanded dramatically in recent years.[2] PV production has been doubling every two years, increasing by an average of 48 percent each year since 2002, making it the world's fastest-growing energy technology.[3] At the end of 2008, according to preliminary data, cumulative global installations reached 15,200 megawatts.[4] PV is best known as a method for generating electric power by using solar cells packaged in PV modules, often electrically connected in multiples as solar PV arrays to convert energy from the sun into electricity. The term PV denotes the unbiased operating mode of a photodiode in which current through the device is entirely due to the transduced light energy. Virtually all PV devices are some type of photodiode. Solar cells produce direct current electricity from light, which can be used to power equipment or to recharge a battery. The first practical application of PV was to power orbiting satellites and other spacecraft, but today the majority of PV modules are used for grid connected power generation.

Cells require protection from the environment and are usually packaged tightly behind a glass sheet. When more power is required than a single cell can deliver, cells are electrically connected together to form photovoltaic modules, or solar panels. A single module is enough to power an emergency telephone, but for a house or a power plant the modules must be arranged in arrays. Although the selling price of modules is still too high to compete with grid electricity in most places, significant financial incentives in Japan and then Germany and Italy triggered a huge growth in demand, followed quickly by production. Perhaps not unexpectedly, a significant market has emerged in off-grid locations for solar-power-charged storage-battery based solutions. These often provide the only electricity available. [5] The EPIA/Greenpeace Advanced Scenario shows that by the year 2030, PV systems could be generating approximately 1,864 GW of electricity around the world. This means that, assuming a serious commitment is made to energy efficiency, enough solar power would be produced globally in twenty-five years' time to satisfy the electricity needs of almost 14% of the world's population. [6]

2.3 DC-DC Converters

There are various dc to dc converters topologies like buck converter, boost converter, buck-boost converter and others converter topology are used in PV charge controller. Since solar panels are only capable of producing a DC voltage, the DC-DC converter becomes quite useful by providing the flexibility to adjust the DC voltage or current at any point in the circuit. DC-DC converters are often preferred in modern electronics since they are smaller, lightweight, provide a high quality output, and more efficient. [7]

2.3.1 Buck (Step-Down) Converter

Regarding this project, several reviews were made. One of the researches made is about buck converter topology which is one of many topologies that were used in PV charge controller development. A buck converter is called a step-down DC to DC converter because the output voltage is less than the input. Its design is similar to the step-up boost converter, and like the boost converter it is a switched-mode power supply that uses two switches (a transistor and a diode) and an inductor and a capacitor. A buck converter can be remarkably efficient (easily up to 95% for integrated circuits) and self-regulating. Most buck converters are designed for continuous-current mode operation compared to the discontinuous-current mode operation. The continuous-current mode operation is characterized by inductor current remains positive throughout the switching period. Conversely, the discontinuous-current mode operation is characterized by inductor current returning to zero during each period. The Figure 2.1 shows the basic of buck converter topology circuit. It alternates between connecting the inductor to source voltage to store energy in the inductor and discharging the inductor into the load.

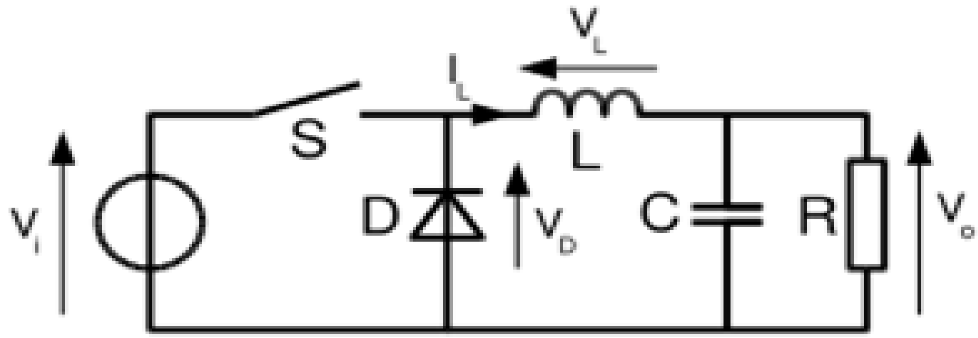

Figure 2.1: A basic buck converter topology circuit

2.3.2 Basic Operation of Buck Converter

<u>Method 1: During ON state</u>

Refer on Figure 2.2, when the switch is in ON state, diode become as reversed biased and the inductor will deliver current and switch conducts inductor current. With the voltage (Vin -Vo) across the inductor, the current rises linearly (current changes, ΔiL). The current through the inductor increase, as the source voltage would be greater then the output voltage and capacitor current may be in either direction depending on the inductor current and load current. When the current in inductor increase, the energy stored also increased. In this state, the inductor acquires energy. Capacitor will provides smooth out of inductor current changes into a stable voltage at output voltage and it's big enough such that V out doesn't change significantly during one switching cycle.

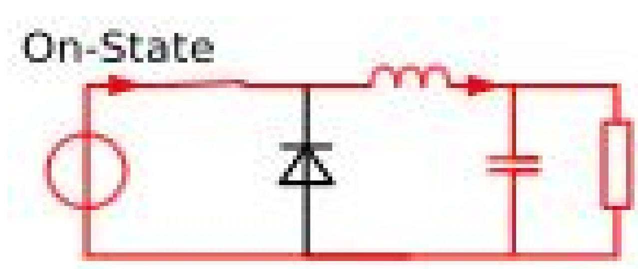

Figure 2.2: Equivalent circuit for switch closed

Method 2: During OFF state

As can see in Figure 2.3, when the switch is in OFF state, the diode is ON and the inductor will maintains current to load. Because of inductive energy storage, iL will continues to flow. While inductor releases current storage, it will flow to the load and provides voltage to the circuit. The diode is forward biased. The current flow through the diode which is inductor voltage is equal with negative output voltage.

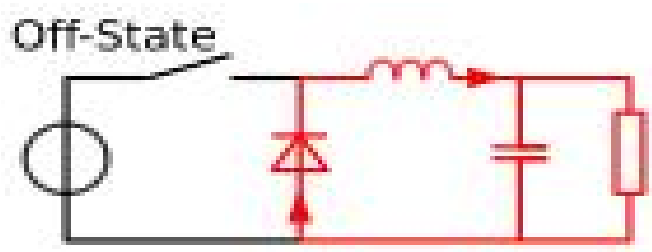

Figure 2.3: Equivalent circuit for switch open

2.4 PIC 16F877A Microcontroller

2.4.1 An overview

The **PIC** (Programmable Interface Controller) line of microcontrollers was originally developed by the semiconductor division of General Instruments Inc (Figure 2.2). The first PIC's were a major improvement over existing microcontroller because they were a programmable, high output current, input/output controller built around a RISC (Reduced Instruction Set Code) architecture. The first PICs ran efficiently at one instruction per internal clock cycle, and the clock cycle was derived from the oscillator divided by 4. Early PICs could run with a high oscillator frequency of 20 MHz. This made them relatively fast for an 8-bit microcontroller, but their main feature was 20 mA of source and sink current capability on each I/O (Input/Output) pin. Typical micros of the time were advertising high I/O currents of only 1 milliampere (mA) source and 1.6 mA sink. [8]

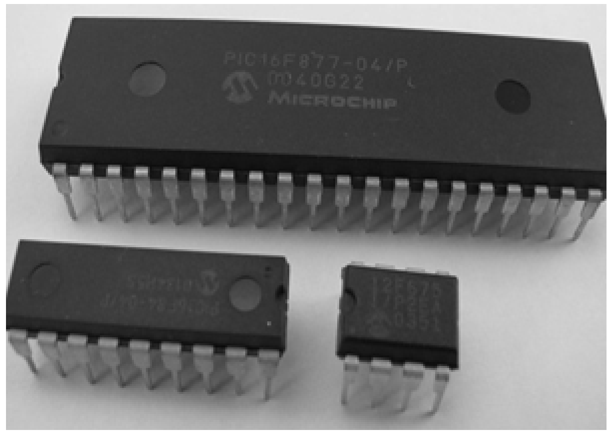

Figure 2.4: Types of PIC Microcontroller

2.4.2 PIC 16F877A Microcontroller Implementation

Regarding this project, several reviews were made. PIC 16F877A microcontroller is selected to monitor voltage and current in PV charge controller. PIC 16F877A is general purpose microprocessor which has additional parts that allow them to control external devices. Basically, a microcontroller executes a user program which is loaded in its program memory. PIC16F877A is a small piece of semiconductor integrated circuits (IC). The package type of these integrated circuits is DIP (Dual Inline Package) package. This package is very easy to be soldered onto the strip board. However using a DIP socket is much easier so that this chip can be plugged and removed from the development board. PIC 16F877A include on-chip PWM units and has two which has a selectable on-time and period. The duty cycle is the ratio of the on-time to the period while the modulating frequency is the inverse of the period.

2.5 Pulse Width Modulation (PWM)

Pulse Width Modulation (PWM) controls adjusts the duty ratio of the switches as the input changes to produce a constant output voltage. The DC voltage is converted to a square-wave signal, alternating between fully on and zero. By controlling analog circuits digitally, system costs and power consumption can be drastically reduced. In nowadays implementation, many microcontrollers already include on-chip PWM controllers, making implementation easy. In a nutshell, PWM is a way of digitally encoding analog signal levels. PWM control can be used in two ways: voltage-mode and current-mode. In voltage-mode control the output voltage increases and decreases as the duty ratio increases and decreases. The output voltage is sensed and used for feedback. If it has two-stage regulation, it will first hold the voltage to a safe maximum for the battery to reach full charge. Then it will drop the voltage lower to sustain a "finish" or "trickle" charge. Two-stage regulating is important for a system that may experience many days or weeks of excess energy (or little use of energy). It maintains a full charge but minimizes water loss and stress. The voltages at which the controller changes the charge rate are called set points. When determining the ideal set points, there is some compromise between charging quickly before the sun goes down, and mildly overcharging the battery. The determination of set points depends on the anticipated pattern of use, the type of battery, and to some extent, the experience and philosophy of the system designer or operator. [9]

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains about hardware development such as equipments, procedures and method design for the photovoltaic (PV) charge controller. The relevant information is gathered through literature review from previous chapter. This chapter also will cover about designing the buck converter, software interface, part by part circuits and complete circuit. Before looking at the details of all methods below, it is best to begin with brief review of the system design.

3.2 Hardware Development

3.2.1 System Design

The photovoltaic (PV) charge controller was designed to protect the rechargeable battery. To design this PV charge controller, it consists of seven parts where the first part is a buck converter circuit, second part is a microcontroller circuit, third part is a driver circuit, four part is rechargeable battery, five part is voltage sensor, six part is current sensor and seven part is liquid crystal display, LCD.

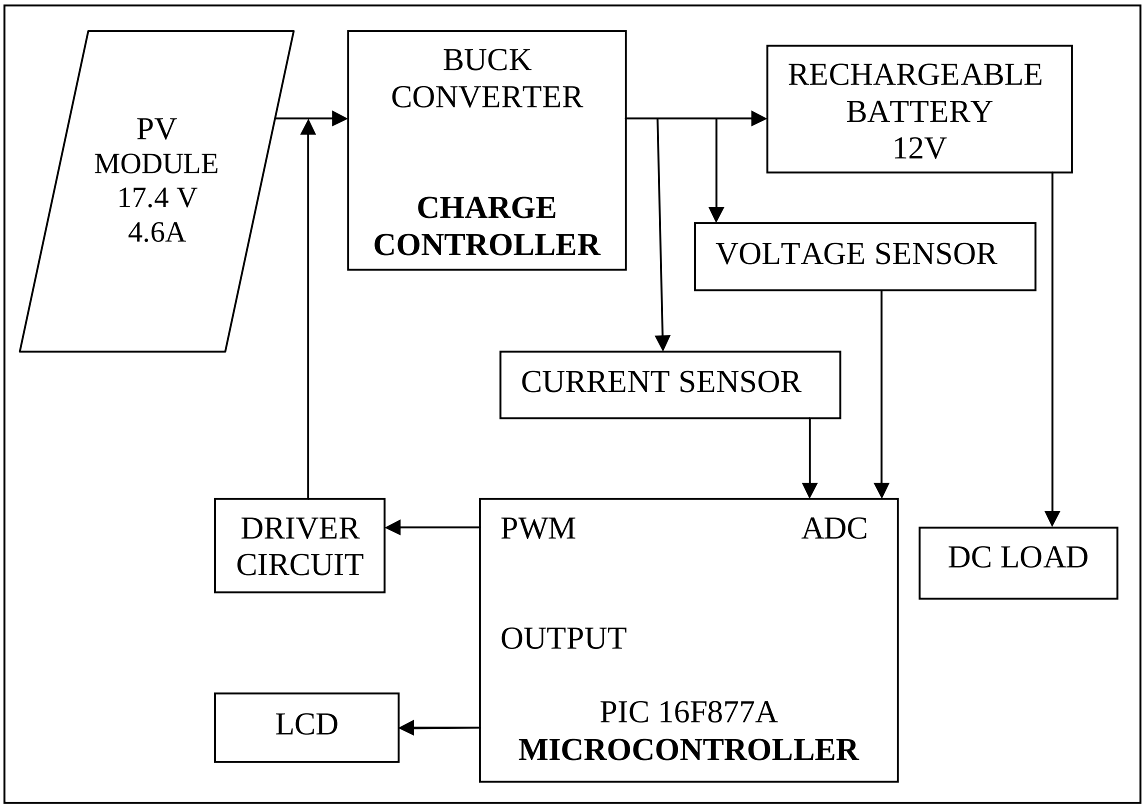

Figure 3.1: System design of Photovoltaic Charge Controller

3.2.2 Buck Converter Circuit Design

For the first part is a buck converter circuit, this circuit is needed in PV charge controller to control charging voltage from PV module to rechargeable battery. The circuit included parts of Buck components such as controllable switch (IRFP150N), diode (1N4148), inductor and capacitor, and load resistor. Some of the designs criteria as show as follow:

i. POWER MOSFET (IRFP150N)

As illustrate in Figure 3.2, this power MOSFET has limitations operation in terms of voltage, current and power dissipation. The power absorbed by the gate drive circuitry should not significantly affect the overall efficiency. The power MOSFET current rating is related with the heat dissipated in the devices. This rating will be take in consideration for designing appropriate circuit to protect power MOSFET against high voltage and current, thus cause heat generation. While considering protection of power MOSFET against over voltage, a distinction has to be made between slowly varying over voltage and short time surge. It is about 100Vdc the minimum rating of drain to source breakdown voltage. Gate voltage must be 15-20V higher than the drain voltage. Being a high side switch, such gate voltage would have to be higher than the rail voltage, which is frequently the higher voltage available in the system. Refer APPENDIX D for details specification. The datasheet provided by manufacturers are given in order to ensure the devices neither connected in the specified limits nor exceeded.

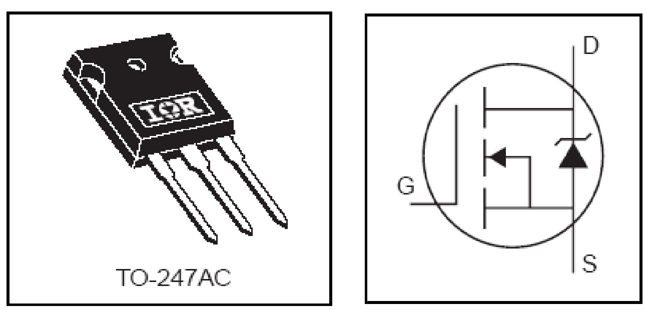

Figure 3.2: IRFP50N terminal pin configuration

ii. Capacitor

Except refer to capacitor value and rating of voltage use in system, the capacitor also supposed to be choose with minimum loss because switched power regulators are usually used in high current-performance power supplies. Loss occurs because of its internal series resistance and inductance. Commonly capacitors for switched regulators are chosen based on the equivalent series resistance (ESR).

iii. Inductor

The function on inductor is to store energy and the value is selected to maintain a continuous current mode (CCM) operation as a rated of load (5.6 Ω) is decided for this Buck converter. In CCM, current flow continuously in inductor during the entire switching cycle and output inductance selected to limit the peak to peak ripple current flowing. The factors to be considered in selecting the inductor are its peak to peak ripple current (CCM), maximum dc or peak current (not overheat) and maximum operating frequency (maximum core loss is not exceeded, resulting in overheating or saturation).

Design of buck converter circuit will consider as continuous current operation mode, CCM. The choice of switching frequency and inductance will affect the continuous current in buck converter design. Just for simple overview about buck converter, as the switching frequency increase, it can reduce the size of inductor in order to produce CCM and reduce capacitor size to limit output ripple in buck converter design.

Here the calculations method and formulas used in order to determine the values of the required components in Buck converter design. This buck converter circuit is needed to produce an output voltage of 12Vdc from an input of 17.4Vdc.

Step 1: Determine the duty cycle, D to obtain required output voltage.

$$D = \frac{Vo}{Vd} \tag{3.1}$$

Where:

D = Duty cycle

Vo = Voltage output

Vd = Voltage input

$$D = \frac{12V}{17.4V}$$

$$D = 0.7$$

$$\%D = 70\%$$

Step 2: Select a particular switching frequency (f) and device

Before Buck converter circuit is design, the pulse width modulation (PWM) frequency should be determined. Basically, if the frequency increases, the efficiency of the Buck converter also increases. Thus to choose a suitable PWM frequency for the Buck converter, both of power consumption and the efficiency of the system need to be consider.

First, we should determine the whole system timing characteristics. The design of Buck converter input voltage should able to be decrease to 70% of its maximum value. Thus, the component at hand is POWER MOSFET IRFP150N for the switching element, IR2109 for the driver and PIC16F877A for the PWM controller. The rise time, tr, the fall time, tf, the minimum on-time, ton (min) and the minimum off-time, toff(min) can be found in the datasheet. Table 3.1 lists the rise and fall times and Table 3.2 lists the on and off times of each components.

Table 3.1: Rise and Fall Time

Bil	Component	tr(ns)	tf(ns)
1	IRFP150N	56	40
2	IR2109	150	50

Table 3.2: Minimum On and Off Time

Bil	Component	tr(ns)	tf(ns)
1	IRFP150N	11	45
2	IR2109	750	200

Referring to Table 1, the slowest tr and tf of the components are 150ns and 50ns respectively. Referring Table 2, it can be seen that both the slowest ton (min) and toff(min) of all components is at MOSFET driver. With the information, the frequency range for the de vice can be determined. A summary of data that we obtained are as follows:

(a) D (min) = 10%
(b) D (max) = 70%
(c) tr (slowest) = 150ns
(d) tf (slowest) = 50ns
(e) ton (min) = 750ns
(f) toff(min) = 200ns

Insert this data in the equation 3.2:

$$\frac{4(1-\mathrm{Dmax})}{3(\mathrm{tr}(\mathrm{slowest})+\mathrm{tf}(\mathrm{slowest}))+4\mathrm{toff}(\min)} \leq \mathrm{fswitch} \leq \frac{4(\mathrm{Dmin})}{\mathrm{tr}(\mathrm{slowest})+\mathrm{tf}(\mathrm{slowest})+4\mathrm{ton}(\min)} \ldots(3.2)$$

$$\frac{4(1-0.7)}{3(150\mathrm{ns}+50\mathrm{ns})+4(200\mathrm{ns})} \leq \mathrm{fswitch} \leq \frac{4(0.1)}{150\mathrm{ns}+50\mathrm{ns}+4(750\mathrm{ns})}$$

$$\frac{1.2}{1400\mathrm{ns}} \leq \mathrm{fswitch} \leq \frac{0.4}{3200\mathrm{ns}}$$

$$857.142\mathrm{kHz} \leq \mathrm{fswitch} \leq 125\mathrm{kHz}$$

Based on the calculation frequency range, the lowest switching frequency is about 125 kHz and the maximum is about up to 857.14 kHz. Thus the switching frequency is set to be 250 kHz. This minimum value is selected in order to minimize power use in Buck converter.

Step 3: Determine minimum inductor, L_{min} size. The switching frequency and inductor size selected for CCM is f = 25 kHz with load resistor, RL=5.6Ω/10W

$$\text{Lmin} = \left(\frac{1-D}{2f}\right)R \tag{3.3}$$

Where:

Lmin	= Minimum inductor
D	= Duty cycle
f	= Frequency
R	= Resistor

$$\text{Lmin} = \left(\frac{1-0.7}{2(250\text{kHz})}\right)5.6\Omega$$

$$\text{Lmin} = \left(\frac{0.3}{500\text{kHz}}\right)5.6\Omega$$

$$\text{Lmin} = 3.36\text{uH}$$

Step 4: To ensure CCM let inductor be 25% greater than minimum inductor value

$$L = 1.25\text{Lmin} \tag{3.4}$$

$$L = 1.25(3.36\text{uH})$$

$$L = 4.2\text{uH}$$

Step 5: The average current and the change in current

$$I_L = \frac{Vo}{R} \tag{3.5}$$

$$I_L = 5A$$

$$\Delta i_L = \frac{Vd - VO}{L}(DT) \tag{3.6}$$

$$\Delta i_L = \frac{17.4V - 12V}{4.2uH}(0.7)\left(\frac{1}{250kHz}\right)$$

$$\Delta i_L = 3.6A$$

Step 6: The maximum inductor current

$$Imax = I_L + \frac{\Delta i_L}{2} \tag{3.7}$$

$$Imax = 5A + \frac{3.6A}{2}$$

$$Imax = 5A + 1.8A$$

$$Imax = 6.8A$$

Step 7: The minimum inductor current

$$Imin = I_L - \frac{\Delta i_L}{2} \tag{3.8}$$

$$Imin = 5A - \frac{3.6A}{2}$$

$$Imin = 5A - 1.8A$$

$$Imin = 3.2A$$

Step 8: The capacitor if output ripple not exceed 2%

$$C = \frac{1 - D}{8L\left(\frac{\Delta Vo}{Vo}\right)f^2} \tag{3.9}$$

Where:

L	= Inductor
D	= Duty cycle
f	= Frequency

$$\frac{\Delta Vo}{Vo} = \text{Ripple factor}$$

$$C = \frac{1-0.7}{8(4.2uH)(0.02)(250kHz^2)}$$

$$C = \frac{0.3}{42k}$$

$$C = 7.2uF$$

Figure 3.3 shows the basic construction of buck converter circuit using software OrCAD PSPICE based on calculations.

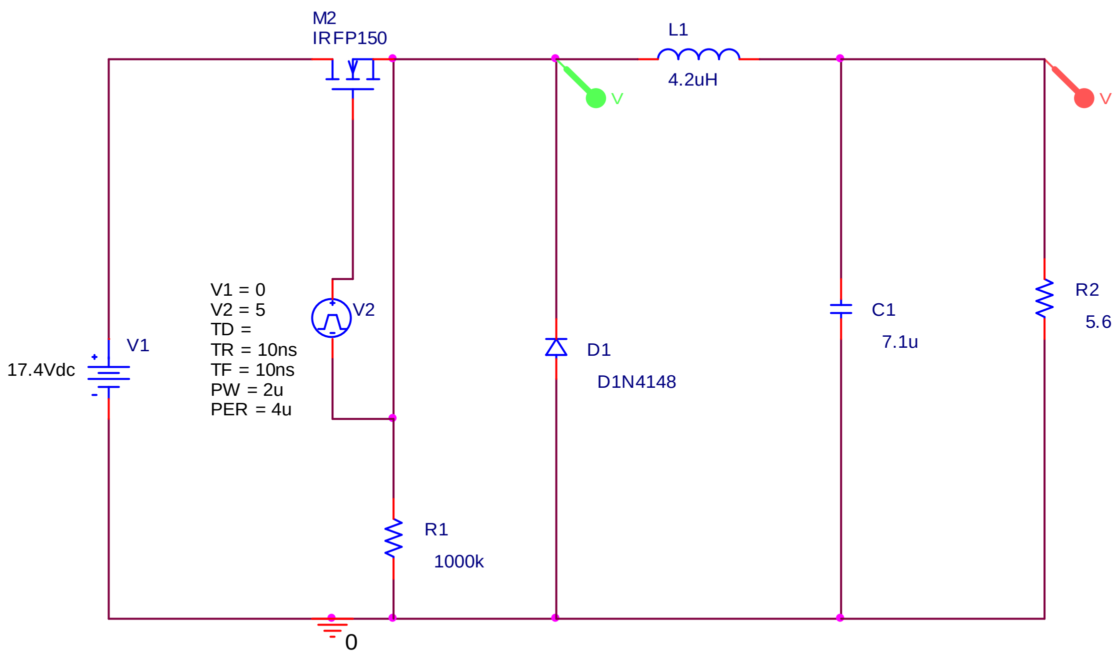

Figure 3.3: OrCAD PSPICE Schematic of Buck Converter.

Once the above schematic is designed, the simulation can be run. Figure 3.4 and 3.5 shows the waveforms generated by PSPICE simulation of the buck converter circuit. The waveform in Figure 3.3 shows the output voltage rising to 12V. We can also see the voltage across the diode during the switch off time is near -3 volts and during the switch on time is near the input voltage. The waveform in Figure 3.4 shows the converter is operating in the continuous conduction mode with an average operating current of about 5A and a peak in-rush current of about 15A.

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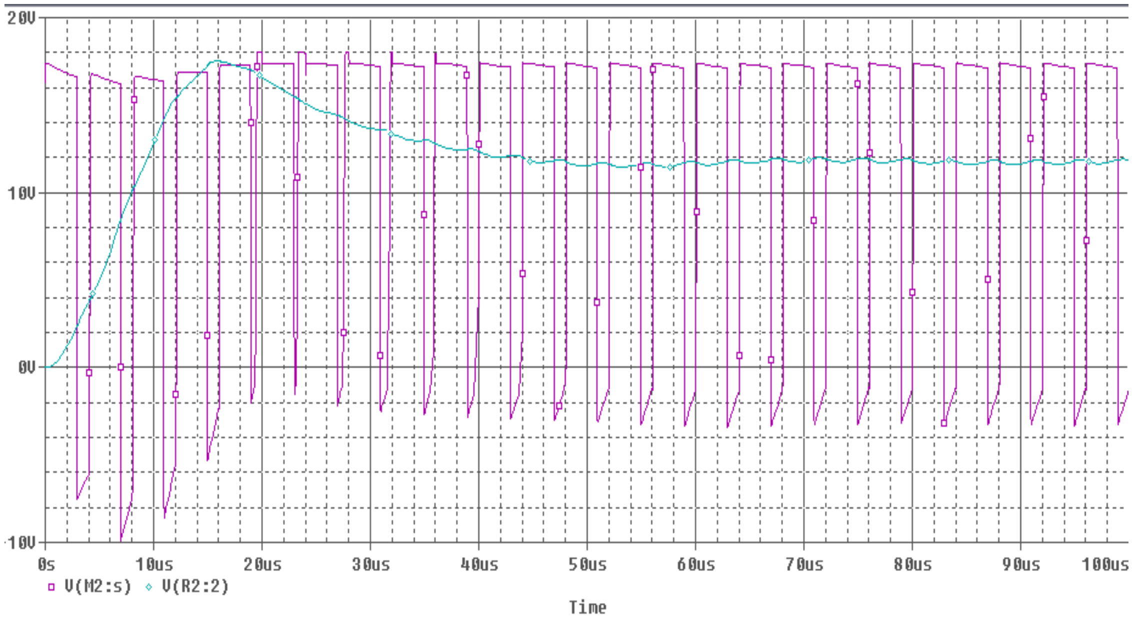

Figure 3.4: PSPICE simulation for V_{in} = 17.4 V; V_{out} = 12 V; D = 0.7

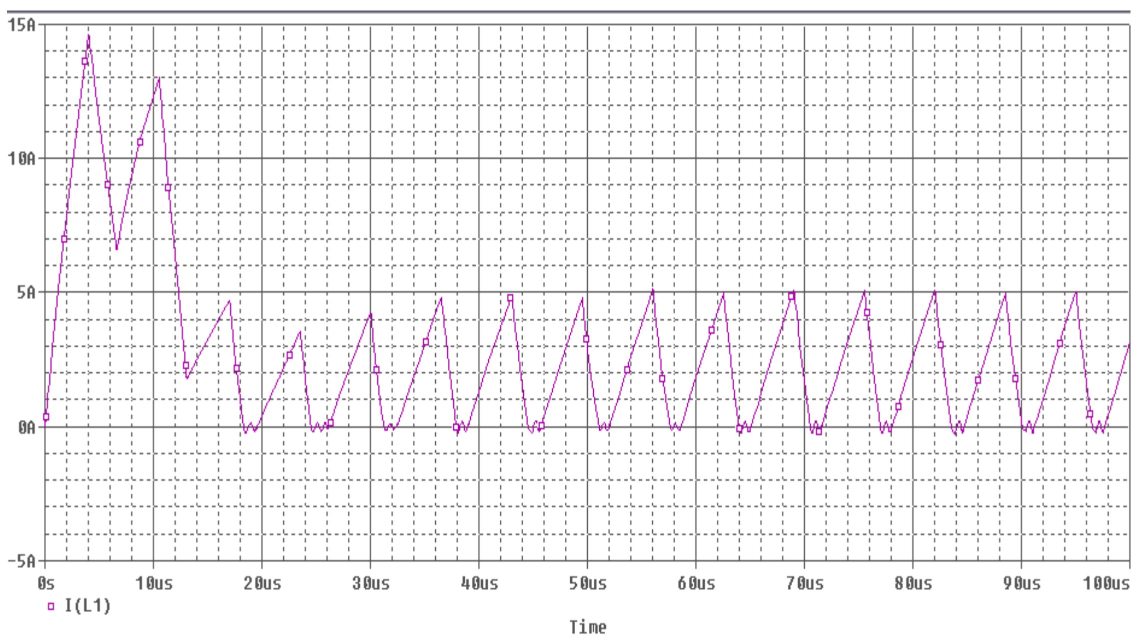

Figure 3.5: PSPICE simulation for i_L = 5A

3.2.3 PIC 16F877A Circuit Design

The second part is a microcontroller circuit. PIC 16F877A microcontroller is used in this PV charge controller to control POWER MOSFET switching duty cycle on the buck converter circuit. PIC 16F877A has 40 pins. This microcontroller offers the advantages which are very easy to be assembled, can be reprogrammed and erased up to 10,000 times and also an economical price. Therefore it is very good for new product development phase. Figure 3.6 show 40 pin PDIP of PIC 16F877A microcontroller.

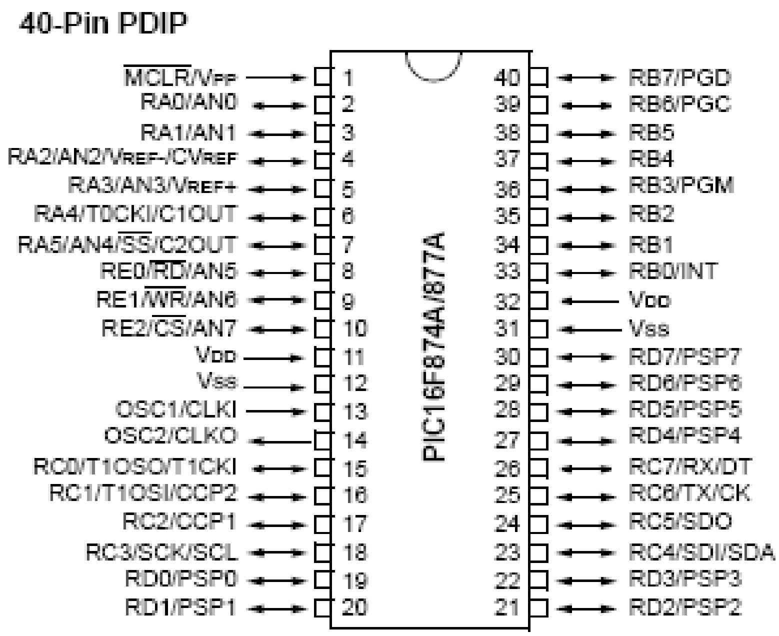

Figure 3.6: 40-Pin PDIP Diagram of PIC 16F887A

Before generate PWM signal from PIC16F877A, there are several circuits that is compulsory for the system to function well. It were included the power supply, clock circuit, and reset circuit. Power supply circuit (Figure 3.7) is needed in the basic PIC16F877A circuitry because 7805 regulator need to regulate the voltage supply of (>6V to 12V) so that the suitable voltage supply will drop at the PIC16F877A Vdd pin12 and make the PIC to functioned.

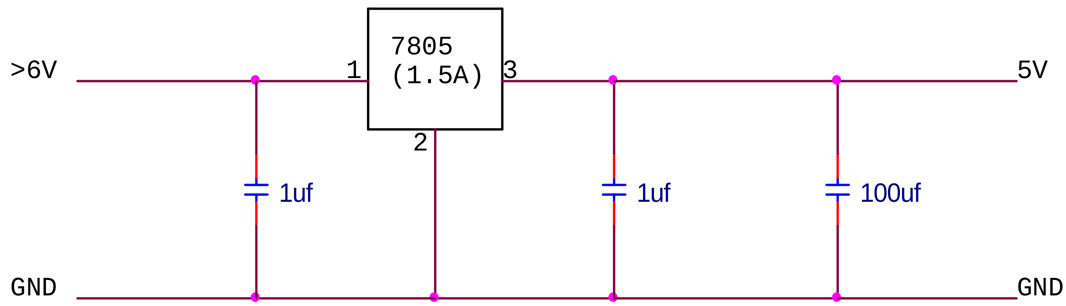

Figure 3.7: PIC 16F877A power supply circuit

A simple RC circuit (Figure 3.8) is used to produce action-synchronizing clock pulses. 20-MHz resonator is used for the operation clock oscillation by PIC 16F877A. The precision of this oscillation frequency doesn't influence the precision of the clock. The precision of the clock is decided by the precision of the frequency which is inputted to pin13 (OSC1) and pin14 (OSC2).

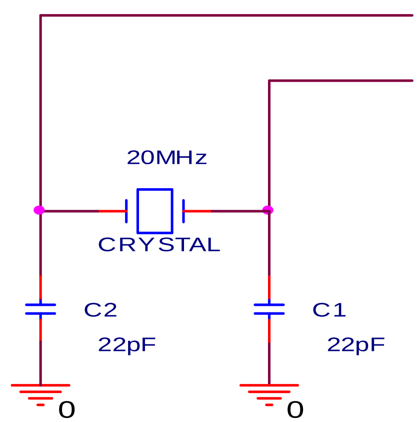

Figure 3.8: PIC 16F877A clock circuit

Meanwhile, the reset circuit (Figure 3.9) is used so that the program from a known state. It will be reset when the Master Clear (/MCLR) pin is connected to the 0V supply (ground). The PIC has internal circuits to perform this function at power on and the simplest design involve merely connecting the /MCLR pin directly to the positive voltage supply through a resistor to the positive voltage supply. When the power supply is connected, the voltage rise too slowly then this reset function may not work. By having a capacitor, at switch on, the capacitor will discharges. The PIC will be held reset until the voltage /MCLR is above threshold value.

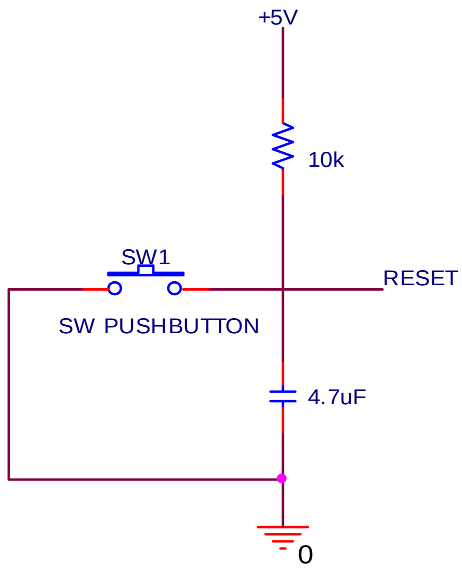

Figure 3.9: PIC 16F877A reset circuit

Since the PWM for Buck converter is sourced by PIC 16F877A in order to maintain the output voltage, the PWM function pin at port RB6 (bit 7 of PORTB) is set to be PWM output and it connecting to IN pin in the IR2109 half bridge driver.

3.2.4 Driver Circuit Design

The third part is a driver circuit. This circuit is really important in this PV charge controller in order to amplify and translate the PWM signal from PIC 16F877A microcontroller to trigger POWER MOSFET (IRFP150N) gate and the high output, HO. HO of driver circuit is connected to the MOSFET IRFP150N gates through resistor and switching diode (IN4148) that is oriented to bypass the resistor during turn-off, to ensure that MOSFET IRFP150N in one leg are fully off by the time another leg is turn on. The resistance is used value 20 Ω which allow a maximum gate turn-on current on the high side. Figure 3.10 show the MOSFET driver circuit.

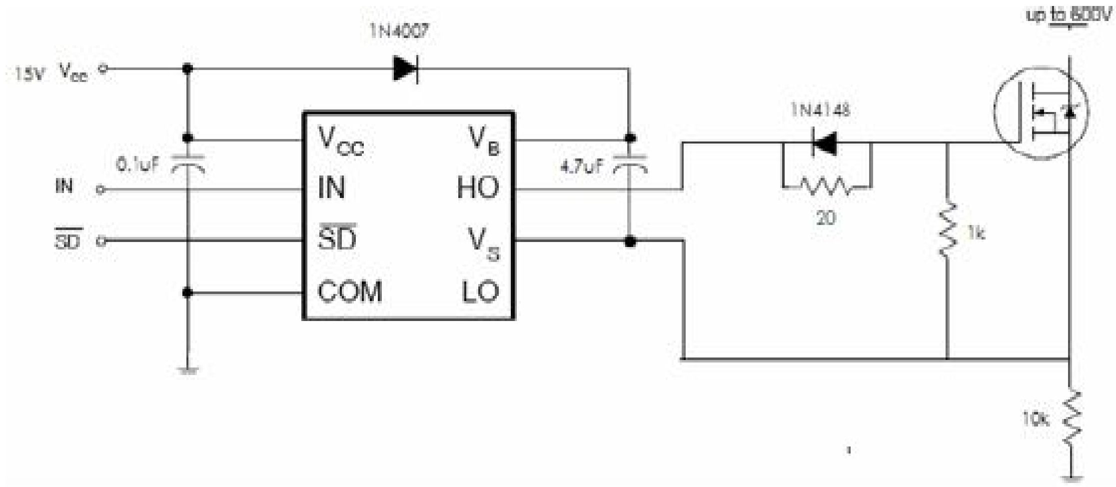

Figure 3.10: Circuit connection for IR2109 half-bridge

Basically, the driver circuit is receives controlled duty cycle signals from the PIC microcontroller at IN pin. The duty cycle signal from microcontroller is small in range about 0Vdc up to 5Vdc maximum. This duty cycle signal received then used for control the power MOSFET switching to the Buck converter. If the output voltage of Buck converter is higher, then the driver will drive a small duty cycle to POWER MOSFET and vise versa. Refer details about high –side driver operation in result discussion.

3.2.4 Rechargeable Battery

The four part is rechargeable battery. This rechargeable battery will be used in PV charge controller is 12V Sealed Lead Acid battery which is stored electrical energy in chemical form to operates dc load at night or bad weather and also requires lower maintenances, has longer life and gives better performance compared to normal battery.